THE CLASSIFICATION OF THE SPECTRUM OF SINGLY IONIZED TIN. Sn II

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The Classification of the Spectrum of Singly Ionized Tin. Sn II

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The spectrum of Sn II, as excited in a hollow cathode discharge in helium, has been photographed from 800A to 10,000A. Some 70 new lines have been classified and 28 new levels established. A few changes have been made in the levels and classifications previously made by Green and Loring, Narayan, and Lang. The $5s^2ms$, $-mp$, $-md$ and $-mf$ series have been extended, and the ^2F levels have been resolved for the first time. Six members of the $5s^2mg\ ^2G$ series have been located and used to make a new determination of the ionization potential of Sn II as 118,017±3 cm^{-1}. The classification has been checked by series relations, Zeeman patterns, and by comparison with the isoelectronic spectra In I and Sb III. Irregularities in the ^2S and ^2D terms are explained qualitatively by consideration of interactions with perturbing terms from the configuration sp^2.

THE first classifications of Sn II were made independently by Green and Loring[1] and by Narayan and Rao[2] and were in substantial agreement. Green and Loring, using vacuum arc data, supplemented by data of R. J. Lang in the extreme ultraviolet, and with the help of a few Zeeman effects, classified thirty of the stronger lines, fixing nineteen low levels. Two levels each were found in the low normal ^2S, ^2P, ^2D and ^2F series, and the ^2D and ^2S levels from the configuration sp^2 were located. Lang[3] later rephotographed the spectrum with a hollow cathode discharge, and made a few corrections and additions, notably the ^4P terms from sp^2. No high terms were found in these researches and the ionization potential was determined only roughly by Green and Loring, who fixed it

[1] Green and Loring, Phys. Rev. **30**, 574 (1927).
[2] Narayan and Rao, Zeits. f. Physik **45**, 350 (1927).
[3] Lang, Phys. Rev. **35**, 445 (1930).

TABLE I. *Unresolved Zeeman patterns of Green and Loring, and computed centers of intensity according to Shenstone and Blair's formula. The observed pattern for each line is given first, the computed pattern is immediately below.*

λ	PATTERN	CLASSIFICATION
3283	(0) 0.91	$p^2\,{}^2D_{3/2}-4^2F_{5/2}$
	0.90	
3352	(0) 1.06	$p^2\,{}^2D_{5/2}-4^2F_{7/2}$
	1.07	
5332	(0) 0.835	$6^2P_{1/2}-6^2D_{3/2}$
	0.833	
5562	(0) 1.04	$6^2P_{3/2}-6^2D_{5/2}$
	1.10	
5589	(0) 0.90	$5^2D_{3/2}-4^2F_{5/2}$
	0.90	
5799	(0) 1.07	$5^2D_{5/2}-4^2F_{7/2}$
	1.07	

by assuming equal effective quantum numbers for the first two members of the ^2F term sequence.

The lowest state of singly ionized lead is $5s^25p\,{}^2P_{1/2}$. Excitation of the $5p$ electron to higher states gives rise to the usual doublet series ^2S, ^2P, ^2D, ^2F—, all of which have as a limit the $5s^2\,{}^1S_0$ term of Sn III. Excitation of one of the two $5s$ electrons leads to configurations of the types $5s5p^2$, $5s5p5d$, $5s5d^2$, etc., with higher limits in the Sn III spectrum. However, a consideration of the energy values in Sn III, corresponding to the excitation of a $5s$ electron to $5p$, $5d$, etc., states, permits a rough calculation of such energies in Sn II. It is easily seen that the only configuration arising from an excited $5s$ electron in Sn II which will lie below the $5s^2$ ionization limits is $5s5p^2$. From this configuration are expected the eight levels $^4P_{1/2,\,3/2,\,5/2}$, $^2D_{3/2,\,5/2}$, $^2P_{1/2,\,3/2}$ and $^2S_{1/2}$. As noted above, six of these terms were found by earlier investigators, in addition to a few low terms in the normal series.

EXPERIMENTAL

The light source chosen for the present investigation was the hollow cathode discharge in an atmosphere of helium. The excitation in this discharge tends to be limited by the reactions between the metal atoms or ions and the metastable or ionized rare gas atoms.[4] The energy of ionization of helium is about 198,000 cm^{-1} while that of Sn I is roughly 59,000 cm^{-1}. Thus there is left available nearly 139,000 cm^{-1} from this reaction for the excitation of the Sn II levels. Since the ionization potential of Sn II is approximately 118,000 cm^{-1}, it is apparent that the Sn II spectrum should be completely excited in this discharge, while the residual energy above that required to doubly ionize tin is not sufficient to excite even the lowest Sn III levels, which lie about 55,000 cm^{-1} higher. The only difficulty in obtaining satisfactory spectra from the discharge arose from the low vapor pressure of tin (boiling point 2260°C), which tends to keep the tin pressure in the discharge too low for the best intensity in the higher excited states of Sn II.

The gas purifying system and excitation conditions have been sufficiently described elsewhere.[5] In the present set-up, the helium was circulated continuously by a mercury vapor pump through a purifying system consisting of suitable traps in liquid air. Current was furnished by a vacuum tube rectifier, the discharge drawing nearly 350 milliamperes. Pure tin was cut into small pieces and placed inside a tungsten cathode, whence it entered the discharge both by temperature evaporation and by bombardment.

The spectrum of the discharge was photographed from 800A to 9000A, a region sufficient to cover all the important lines of the tin spark spectrum. The region of wave-lengths shorter than λ2200 was photographed with a concave grating vacuum spectrograph.[6] The grating (1 m radius, 14,400 lines per inch) gave a dispersion of about 17A/mm. Satisfactory standards of wave-length were found among the O, He, and Hg lines which appeared in the discharge. The region from 2200A to 2700A was photographed with a Hilger E2 quartz spectrograph, while for the regions 2500A to 4500A and 4500A to 10,000A, a Hilger E1 quartz and a glass spectrograph of comparable dimensions were used. Iron arc comparison spectra were placed on all plates through the quartz and glass regions up to 8000A. Above 8000A a neon comparison spectrum was used. All plates were measured on a Gaertner comparator. The calculated wave-lengths in air were reduced to wave numbers in vacuum with the help of Kayser's table. For wave-lengths greater than 2200A, the wave number values are probably correct, in most cases, to about one wave per centimeter;

[4] Sawyer, Phys. Rev. **36**, 44 (1930).

[5] Sawyer and Paschen, Ann. d. Physik **84**, 1 (1927).

[6] Sawyer, J. Opt. Soc. Am. **15**, 305 (1927).

for the wave-lengths from the vacuum spectrograph, the error is somewhat greater and may be as high as 10 cm^{-1} for the shortest wave-lengths and weakest lines.

Data and Classification

Green and Loring,[1] in their work on the tin spectra, determined the Zeeman effects of eight Sn II lines. Only two of the pat-

Table II. *Classified lines in* Sn II.

I	λ Vac.	ν Vac.	Classification	$\Delta\nu$	Notes	I	λ Air	ν Vac.	Classification	$\Delta\nu$	Notes
0	888.38	112,564	$5^2P_{1/2}-11^2D_{3/2}$	7		1	2912.80	34,321	$5^2D_{5/2}-9^2P_{3/2}$	0	
1	899.92	111,121	$5^2P_{1/2}-10^2D_{3/2}$	−1		6	2919.82	34,239	$6^2P_{1/2}-8^2D_{3/2}$	1	
2	917.40	109,004	$5^2P_{1/2}-9^2D_{3/2}$	−1		0	2943.60	33,962	$5^2D_{3/2}-6^2F_{5/2}$	0	
0	923.07	108,334	$5^2P_{3/2}-11^2D_{5/2}$	−2		3	2991.00	33,424	$p^2\,^2D_{3/2}-7^2P_{3/2}$	0	
1	935.63	106,880	$5^2P_{3/2}-10^2D_{5/2}$	4		7	2994.44	33,386	$6^2P_{3/2}-8^2D_{5/2}$	0	
3	945.83	105,728	$5^2P_{1/2}-8^2D_{3/2}$	2		0	2997.13	33,356	$6^2P_{3/2}-8^2D_{3/2}$	0	
4	954.50	104,767	$5^2P_{3/2}-9^2D_{5/2}$	4		1	3012.18	33,189	$6^2P_{1/2}-9^2S_{1/2}$	0	
7	985.13	101,508	$5^2P_{3/2}-8^2D_{5/2}$	0		8	3023.94	33,060	$p^2\,^2D_{3/2}-7^2P_{1/2}$	−1	
0	995.77	100,425	$5^2P_{3/2}-9^2S_{1/2}$	2		12	3047.50	32,804	$p^2\,^2D_{5/2}-7^2P_{3/2}$	0	
4	997.21	100,280	$5^2P_{1/2}-7^2D_{3/2}$	0		6	3094.69	32,304	$6^2P_{3/2}-9^2S_{1/2}$	1	*g*
2	1016.26	98,400	$5^2P_{1/2}-8^2S_{1/2}$	−1		50	3283.21	30,449	$p^2\,^2D_{3/2}-4^2F_{5/2}$	−1	*x*
4	1040.78	96,082	$5^2P_{3/2}-7^2D_{5/2}$	0		60	3351.97	29,824	$p^2\,^2D_{5/2}-4^2F_{7/2}$	0	*x, l*
1	1041.32	96,032	$5^2P_{3/2}-7^2D_{3/2}$	−4		0	3355.55	29,793	$5^2D_{3/2}-8^2P_{1/2}$	2	
3	1062.10	94,153	$5^2P_{3/2}-8^2S_{1/2}$	−6		2	3407.48	29,339	$5^2D_{5/2}-8^2P_{3/2}$	−1	
8	1108.19	90,237	$5^2P_{1/2}-6^2D_{3/2}$	1	*x*	10	3472.46	28,790	$6^2P_{1/2}-7^2D_{3/2}$	0	
4	1159.05	86,277	$5^2P_{1/2}-7^2S_{1/2}$	−1	*y, a*	7	3537.57	28,260	$5^2D_{3/2}-5^2F_{5/2}$	2	*y, i*
10	1161.43	86,101	$5^2P_{3/2}-6^2D_{5/2}$	−5	*x*	11	3575.45	27,960	$6^2P_{3/2}-7^2D_{5/2}$	0	*y, k*
3	1162.94	85,989	$5^2P_{3/2}-6^2D_{3/2}$	−3	*x*	3	3582.39	27,906	$6^2P_{3/2}-7^2D_{3/2}$	0	
4	1180.51	84,709	$5^2P_{1/2}-p^2\,^2P_{3/2}$	−3	*x, b*	*c*	3587.33	27,867	$p^2\,^4P_{1/2}-6^2P_{3/2}$		*h*
9	1219.07	82,030	$5^2P_{3/2}-7^2S_{1/2}$	−6	*y, a*	2	3620.08	27,616	$5^2D_{5/2}-5^2F_{5/2}$	0	*i*
13	1223.70	81,719	$5^2P_{1/2}-p^2\,^2S_{1/2}$	0	*x, y*	6	3620.54	27,612	$5^2D_{5/2}-5^2F_{7/2}$	0	*y, i*
11	1243.00	80,450	$5^2P_{3/2}-p^2\,^2P_{3/2}$	4	*x, y, b*	*c*	3705.10	26,981	$p^2\,^4P_{1/2}-6^2P_{1/2}$		*h*
20	1290.86	77,467	$5^2P_{3/2}-p^2\,^2S_{1/2}$	0	*x, y*	6	3715.23	26,909	$6^2P_{1/2}-8^2S_{1/2}$	0	
20	1316.59	75,953	$5^2P_{3/2}-p^2\,^2P_{1/2}$	0		4	3841.44	26,024	$6^2P_{3/2}-8^2S_{1/2}$	1	
25	1400.52	71,402	$5^2P_{1/2}-5^2D_{3/2}$	3	*x*	0	3984.77	25,088	$4^2F_{7/2}-11^2G$	0	
20	1475.15	67,795	$5^2P_{3/2}-5^2D_{5/2}$	0	*x*	0	3994.51	25,027	$p^2\,^4P_{3/2}-6^2P_{1/2}$	0	
9	1489.22	67,149	$5^2P_{3/2}-5^2D_{3/2}$	4	*x*	0	4110.51	24,321	$4^2F_{7/2}-10^2G$	0	
7	1699.47	58,842	$5^2P_{1/2}-p^2\,^2D_{3/2}$	0	*x, y, c*	0	4111.59	24,315	$4^2F_{5/2}-10^2G$	0	
7	1758.00	56,883	$5^2P_{1/2}-6^2S_{1/2}$	0	*x*	0	4293.61	23,284	$4^2F_{7/2}-9^2G$	0	
15	1811.34	55,208	$5^2P_{3/2}-p^2\,^2D_{5/2}$	2	*x*	1	4294.65	23,278	$4^2F_{5/2}-9^2G$	0	
9	1831.89	54,588	$5^2P_{3/2}-p^2\,^2D_{3/2}$	2	*x, c*	1	4579.13	21,832	$4^2F_{7/2}-8^2G$	0	
12	1899.91	52,634	$5^2P_{3/2}-6^2S_{1/2}$	−3	*x*	1	4580.29	21,826	$4^2F_{5/2}-8^2G$	0	
1	2149.31	46,527	$p^2\,^2D_{3/2}-6^2F_{5/2}$	2		0	4792.22	20,861	$5^2D_{3/2}-7^2P_{3/2}$	0	
30	2152.22	46,464	$5^2P_{1/2}-p^2\,^4P_{3/2}$	−1	*y*	2	4877.22	20,498	$5^2D_{3/2}-7^2P_{1/2}$	0	
						3	4944.31	20,219	$5^2D_{5/2}-7^2P_{3/2}$	0	
	λ Air	ν Vac.				2	5071.14	19,714	$4^2F_{7/2}-7^2G$	0	
4	2209.67	45,241	$5^2P_{3/2}-p^2\,^4P_{5/2}$	0	*y*	2	5072.67	19,708	$4^2F_{5/2}-7^2G$	0	
6	2246.07	44,509	$5^2P_{1/2}-p^2\,^4P_{1/2}$	0	*y*	10	5332.36	18,748	$6^2P_{1/2}-6^2D_{3/2}$	0	*x, l*
3	2360.34	42,354	$p^2\,^2D_{3/2}-8^2P_{1/2}$	0		20	5561.95	17,974	$6^2P_{3/2}-6^2D_{5/2}$	0	*x, l*
22	2368.33	42,211	$5^2P_{3/2}-p^2\,^4P_{3/2}$	0	*y*	25	5588.92	17,887	$5^2D_{3/2}-4^2F_{5/2}$	0	*x, l*
4	2384.54	41,924	$p^2\,^2D_{5/2}-8^2P_{3/2}$	−1		2	5596.20	17,864	$6^2P_{3/2}-6^2D_{3/2}$	0	*x, l*
1	2433.52	41,080	$6^2P_{1/2}-11^2D_{3/2}$	1	*d*	1	5797.20	17,245	$5^2D_{5/2}-4^2F_{5/2}$	0	
15	2448.98	40,821	$p^2\,^2D_{3/2}-5^2F_{5/2}$	0	*y, e*	15	5799.18	17,239	$5^2D_{5/2}-4^2F_{7/2}$	0	*x, l*
13	2483.48	40,254	$5^2P_{3/2}-p^2\,^4P_{1/2}$	3	*y*	0	5965.69	16,758	$7^2P_{3/2}-9^2D_{5/2}$	−1	
10	2486.99	40,197	$p^2\,^2D_{5/2}-5^2F_{7/2}$	0	*y, e*	6	6077.48	16,449	$4^2F_{7/2}-6^2G$	0	
5	2522.61	39,630	$6^2P_{1/2}-10^2D_{3/2}$	0		5	6079.70	16,443	$4^2F_{5/2}-6^2G$	0	
0	2579.08	38,762	$6^2P_{3/2}-10^2D_{5/2}$	0		70	6453.50	15,491	$6^2S_{1/2}-6^2P_{3/2}$	0	*x*
0	2608.67	38,322	$6^2P_{3/2}-11^2S_{1/2}$	0		8	6761.45	14,786	$6^2P_{1/2}-7^2S_{1/2}$	0	
2	2664.93	37,513	$6^2P_{1/2}-9^2D_{3/2}$	0		25	6844.05	14,608	$6^2S_{1/2}-6^2P_{1/2}$	1	*x*
0	2711.74	36,866	$6^2P_{1/2}-10^2S_{1/2}$	0		20	7191.40	13,902	$6^2P_{3/2}-7^2S_{1/2}$	0	
2	2727.82	36,648	$6^2P_{5/2}-9^2D_{5/2}$	1		10	7387.79	13,532	$p^2\,^2D_{3/2}-6^2P_{3/2}$	0	
0	2778.34	35,982	$6^2P_{3/2}-10^2S_{1/2}$	0		1	7408.62	13,494	$7^2P_{3/2}-8^2D_{5/2}$	0	
2	2825.52	35,381	$6^2S_{1/2}-7^2P_{3/2}$	−2	*f*	13	7741.80	12,913	$p^2\,^2D_{5/2}-6^2P_{3/2}$	1	
1	2846.42	35,121	$6^2S_{1/2}-7^2P_{1/2}$	1	*f*	3	7904.00	12,648	$p^2\,^2D_{3/2}-6^2P_{1/2}$	0	

x, Classified by Green and Loring.
y, Classified by Lang.
a, Our measurements are about an angstrom higher than Lang's.
b, Green and Loring classified as $5^2P_{1/2,\ 3/2}-7^2S_{1/2}$.
c, Lang's classification has the *j* values interchanged.
d, May be the line 2433.473 classified in Sn I by Green and Loring.
e, Green and Loring gave λ2849.8 and λ2488 for this pair.
f, Green and Loring used λ2789.32 and λ2761.78 for this pair.
g, An OH line falls on the tin line.
h, These lines are covered by rather strong helium lines.
i, Green and Loring used λ3624.6 and λ3540.0 for this pair.
k, Lang classified as $6^2P_{1/2}-7^2D_{1/2}$.
l, Our measurements on these strong lines are lower than those of Green and Loring by 0.5 to 0.9A, perhaps because of the greater sharpness of the lines from the hollow cathode.

terns were resolved, λ6453 $6^2P_{3/2}-6^2S_{1/2}$ and λ5596 $6^2D_{1/2}-6^2P_{3/2}$, and gave patterns in complete agreement with the assignments. However, the later work of Shenstone and Blair[7] permits the calculation of the center of intensity of unresolved patterns. Table I shows the results of such a calculation for the remaining magnetic measurements of Green and Loring on Sn II lines. In this table, for each line, is given the separation observed by Green and Loring and, immediately below it, that to be expected from the formula of Shenstone and Blair for the classification given by Green and Loring. The correctness of the assignments is established by the good agreement. The 6^2P, 5^2D, 5^2D and $p^2\ ^2D$ differences are thus established and these differences, together with the 5^2P difference of Green and Loring, which was assumed to be correct, formed a starting point for further classification.

It was found possible to extend all the doublet series beyond the two members already known. The 4^2F and 5^2F terms were resolved for the first time and found to be inverted. The 4^2F-m^2G series were discovered and six terms measured, and the $p^2\ ^2P$ term located. In all, over 100 lines

TABLE III. *Term values in* Sn II, *with separations and effective quantum numbers. Previously determined terms are italicized. All others are new.*

	4	5	6	7	8	9	10	11
$^2S_{1/2}$			*61134*	*31741*	19618	13338	9661	7321
n^*			2.680	3.719	4.730	5.737	6.741	7.743
$^2P_{1/2}$		*118017*	*46527*	26114	16821			
n^*		1.929	3.072	4.100	5.108			
		4252	884	363	191			
$^2P_{3/2}$		*113765*	*45643*	25751	16630	11649		
n^*		1.965	3.101	4.129	5.138	6.139		
$^2D_{3/2}$		*46612*	*27779*	17737	12287	9014	6897	5446
n^*		3.069	3.975	4.975	5.977	6.978	7.978	8.978
		642	110	54	30	20	16	13
$^2D_{5/2}$		*45970*	*27669*	17683	12257	8994	6881	5433
n^*		3.090	3.983	4.982	5.984	6.986	7.987	8.988
$^2F_{5/2}$	*28725*	*18354*	12650					
n^*	3.909	4.891	5.891					
	−6	−4						
$^2F_{7/2}$	28731	18358						
n^*	3.909	4.890						
$^2G_{7/2,\ 9/2}$			12282	9017	6899	5447	4410	3643
n^*			5.978	6.977	7.977	8.977	9.977	10.977
$6s6p^2$	$^4P_{1/2}$ *78508*		$^2D_{3/2}$	*59175*	$^2P_{1/2}$	37812		
	$^4P_{3/2}$ *71554*		$^2D_{5/2}$	*58555*	$^4P_{3/2}$	33311	$^2S_{1/2}$	*36298*
	$^4P_{5/2}$ *68524*							

TABLE IV. *Unclassified lines of tin. The lines given by Arnolds are marked with an asterisk. The other lines are new.*

INTENSITY	λ AIR	ν VAC.	INTENSITY	λ AIR	ν VAC.
* 9	2265.98	44,116	*13	3413.03	29,291
9	2419.49	41,318	10	3102.23	32,226
*10	2445.01	40,887	* 9	3122.51	32,016
8	2504.59	39,915	*40	3223.59	31,012

were classified and are given in Table II. Lines classified by other experimenters and changes made by the authors in previous classifications are indicated in the notes. The classified lines determine 48 terms, which are given in Table III, together with the separations and effective quantum numbers of the doublet series members. The term values here given are based on a new value of the ionization potential (118,017±3 cm^{-1}). This value was determined by adjusting the term values of the ^2G series until the quantum defects approached constancy, which could be done with an uncertainty of about one wave number. The accuracy of the determination of the ionization potential is then limited by the uncertainty in fixing the $5^2P_{1/2}$ level on the basis of the vacuum data for transitions to this term. Since there are several such transitions the uncertainty is much less than in a single measurement and is probably about ±3 cm^{-1}.

The $p^2\ ^2P$ terms had not been located previously, but Lang's suggestion that the pair λλ1180.51 and 1243.00 formed part of the $^2P\ ^2P'$ multiplet was adopted and the remaining pair searched for. A strong line at 1316.59A is probably one line of this pair but its companion, $p^2\ ^2P_{1/2}-5^2P_{1/2}$, was not found. The location of these terms may be checked approximately by the relation given by Bacher and Goudsmit[8] which states that, for Russell-Saunders coupling, the interval between the terms ^4P and ^2P from the configuration sp^2 should be three halves the interval between the ^3P and ^1P terms of the corresponding configuration of the once more ionized atom when the intervals are measured between the centers of gravity of the terms. The $5s5p^2(^4P-^2P)$ difference in Sn II is about 35,000 cm^{-1} while the $5s5p(^3P-^1P)$ interval in Sn III is 22,600 cm^{-1}. The ratio is, then, 1.57.

[7] Shenstone and Blair, Phil. Mag. **8**, 765 (1929).

[8] Bacher and Goudsmit, Phys. Rev. **46**, 948 (1934).

The agreement is good considering the fact that the coupling is probably not extreme Russell-Saunders.

The lines given in Table IV are the only ones of considerable intensity in the data which are unassigned. Those marked with a star were listed by Arnolds[9] as tin lines. Some of the stronger unclassified lines may belong to the arc spectrum of tin, although they do not fit in the existing term scheme.[1]

Perturbations

A consideration of the effective quantum numbers in Table III indicates that the ^2P and ^2F series are regular, as is to be expected in view of the absence of perturbing terms of the same parity. Likewise, the ^2G terms are expected to be regular, since they have no J values in common with the other even terms.

Irregularities occur, however, among the other even terms; the 7^2S term is displaced somewhat from the predicted location while the 5^2D terms are markedly displaced and have a larger separation than expected. These irregularities are shown graphically in Fig. 1, where the Rydberg correction term a is plotted against the principal quantum number n. The fact that the quantum numbers of these terms are higher than expected is interpreted as being due to repulsion from the lower lying perturbing terms $p^2\,^2S$ and $p^2\,^2D$. The perturbing terms, themselves, are probably displaced downward because of the interaction. Thus the $p^2\,^2S$ term is found between the $p^2\,^2P$ terms, whereas its normal position would be above them. A rough calculation, assuming the Slater interval relations,[10] indicates that the $p^2\,^2D$ terms are lower by some 9000 cm^{-1} than their predicted position. These series terms and the corresponding perturbing terms share characteristics to such an extent that it is nearly impossible to distinguish between them.

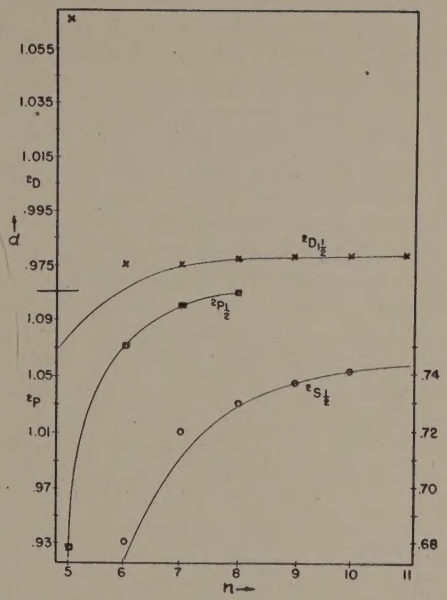

FIG. 1. Irregularities in the ^2S and ^2D terms of Sn II, as shown by plot of the Rydberg correction term, a, vs. principal quantum number, n.

Comparisons with the isoelectronic spectra In I and Sb III were made by investigation of the regular and the irregular doublet laws. Unfortunately, data on these spectra are not very complete so that the number of comparisons which could be made was not large.

From the expression:

$$\Delta\nu=\frac{R\alpha^2(Z-s)^4}{n^3l(l+1)}$$

the values of the screening constant s have been computed and are shown in Table V. The agreement is satisfactory for heavy atoms, particularly in view of the existing perturbations. The large changes in the values of s for the $5D$ terms of successive isoelectronic spectra is indicative of the perturbation of these terms by the $p^2\,^2D$ terms.

TABLE V. *The regular doublet law. Values of the screening constant, s, from the relation* $\Delta\nu=\frac{R\alpha^2(Z-s)^4}{n^3l(l+1)}$.

	$5P$	$6P$	$7P$	$8P$	
In I	31.44		38.30	39.04	
Sn II	29.32	33.99	35.62	36.55	
Sb III	27.94	32.24			
	$5D$	$6D$	$7D$	$8D$	$9D$
In I	41.58	38.73	39.21	39.13	
Sn II	33.04	37.49	38.24	38.78	38.93
Sb III	27.80	35.84			

[9] Arnolds, Zeits. f. Wiss. Phot. **13**, 313 (1913–14).

[10] Slater, Phys. Rev. **34**, 1293 (1929).

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